DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
Submission of Proposals

DARPA's charter is to help maintain U.S. technological superiority over, and to prevent technological surprise by, its potential adversaries. Thus, the DARPA goal is to pursue as many highly imaginative and innovative research ideas and concepts with potential military and dual-use applicability as the budget and other factors will allow.

DARPA has identified technical topics to which small businesses may respond in the second fiscal year (FY) 2002 solicitation (FY 2002.2). Please note that these topics are UNCLASSIFIED and only UNCLASSIFIED proposals will be entertained. Although they are unclassified, the subject matter may be considered to be a "critical technology". If you plan to employ NON-U.S. Citizens in the performance of a DARPA SBIR contract, please inform the Contracting Officer who is negotiating your contract. These are the only topics for which proposals will be accepted at this time. A list of the topics currently eligible for proposal submission is included followed by full topic descriptions. The topics originated from DARPA technical program managers and are directly linked to their core research and development programs.

Please note that **1 original and 4 copies** of each proposal must be mailed or hand-carried. DARPA will **not** accept proposal submissions by electronic facsimile (fax). A checklist has been prepared to assist small business activities in responding to DARPA topics. Please use this checklist prior to mailing or hand-carrying your proposal(s) to DARPA. Do not include the checklist with your proposal.

DARPA Phase I awards will be Firm Fixed Price contracts.

Phase I proposals **shall not exceed $99,000**, and may range from 6 to 8 months in duration. Phase I contracts cannot be extended.

DARPA Phase II proposals must be invited by the respective Phase I technical monitor (with the exception of Fast Track Phase II proposals – see Section 4.5 of this solicitation). DARPA Phase II proposals must be structured as follows: the first 10-12 months (base effort) should be approximately $375,000; the second 10-12 months of incremental funding should also be approximately $375,000. The entire Phase II effort should generally not exceed $750,000.

It is expected that a majority of the Phase II contracts will be Cost Plus Fixed Fee. However, DARPA may choose to award a Firm Fixed Price Contract or an Other Transaction, on a case-by-case basis.

Prior to receiving a contract award, the small business **MUST** be registered in the Centralized Contractor Registration (CCR) Program. You may obtain registration information by calling 1-888-352-9333 or Internet: http://www.ccr.dlsc.dla.mil.

The responsibility for implementing DARPA's SBIR Program rests in the Contracts Management Office. The DARPA SBIR Program Manager is Ms. Connie Jacobs. DARPA invites the small business community to send proposals directly to DARPA at the following address:

DARPA/CMO/SBIR
Attention: Ms. Connie Jacobs
3701 North Fairfax Drive
Arlington, VA 22203-1714
(703) 526-4170
Home Page http://www.darpa.mil

SBIR proposals will be processed by the DARPA Contracts Management Office and distributed to the appropriate technical office for evaluation and action.

DARPA selects proposals for funding based on technical merit and the evaluation criteria contained in this solicitation document. DARPA gives evaluation criterion a., "The soundness and technical merit of the proposed approach and its incremental progress toward topic or subtopic solution" (refer to section 4.2 Evaluation Criteria - Phase I), twice the weight of the other two evaluation criteria. As funding is limited, DARPA reserves the right to select and fund only those proposals considered to be superior in overall technical quality and highly relevant to the DARPA mission. As a result, DARPA may fund more than one proposal in a specific topic area if the technical quality of the proposal(s) is deemed superior, or it may not fund any proposals in a topic area. Each proposal submitted to DARPA must have a topic number and must be responsive to only one topic.

Cost proposals will be considered to be binding for 180 days from closing date of solicitation.

Successful offerors will be expected to begin work no later than 30 days after contract award.

For planning purposes, the contract award process is normally completed within 45 to 60 days from issuance of the selection notification letter to Phase I offerors.

The DoD SBIR Program has implemented a Fast Track process for SBIR projects that attract matching cash from an outside investor for the Phase II SBIR effort, as well as for the interim effort between Phases I and II. Refer to Section 4.5 for Fast Track instructions. DARPA encourages Fast Track Applications ANYTIME during the 6th month of the Phase I effort. The Fast Track Phase II proposal must be submitted no later than the last business day in the 7th month of the effort. **Technical dialogues with DARPA Program Managers are encouraged to ensure research continuity.** If a Phase II contract is awarded under the Fast Track program, the amount of the interim funding will be deducted from the Phase II award amount. It is expected that interim funding generally, will not exceed $40,000.

To encourage the transition of SBIR research into DoD Systems, DARPA has implemented a Phase II Enhancement policy. Under this policy DARPA will provide a Phase II company with additional Phase II SBIR funding, not to exceed $200K, if a DARPA Program Manager can match the additional SBIR funds with DARPA core-mission funds or the company can match the money with funds from private investors; or at the discretion of the DARPA Program Manager. DARPA will generally provide the additional Phase II funds by modifying the Phase II contract.

DARPA FY2002.2 Phase I SBIR
Checklist

1) Proposal Format

   a. Cover Sheet (formerly referred to as Appendices A and B) **MUST** be submitted electronically (identify topic number) ______

   b. Identification and Significance of Problem or Opportunity ______

   c. Phase I Technical Objectives ______

   d. Phase I Work Plan ______

   e. Related Work ______

   f. Relationship with Future Research and/or Development ______

   g. Commercialization Strategy ______

   h. Key Personnel, Resumes ______

   i. Facilities/Equipment ______

   j. Consultants ______

   k. Prior, Current, or Pending Support ______

   l. Cost Proposal (see Appendix C of this Solicitation). Ensure your cost proposal is signed. ______

   m. Company Commercialization Report (formerly referred to as Appendix E) ______
   MUST be registered electronically and a signed hardcopy submitted with your proposal
   (register at http://www.dodsbir.net/submission/)

2) Bindings

   a. Staple proposals in upper left-hand corner. ______

   b. **<u>DO NOT</u>** use a cover. ______

   c. **<u>DO NOT</u>** use special bindings. ______

3) Page Limitation

   a. Total for each proposal is 25 pages inclusive of cost proposal and resumes. ______

   b. Beyond the 25 page limit do not send appendices, attachments and/or additional references. ______

   c. Company Commercialization Report (formerly referred to as Appendix E) **IS NOT** included in the page count. ______

4) Submission Requirement for Each Proposal

   a. Original proposal, including signed Cover Sheet (formerly referred to as Appendix A) ______

   b. Four photocopies of original proposal, including signed Cover Sheet and Company Commercialization Report (formerly referred to as Appendices A, B and E) ______

INDEX OF DARPA FY2002.2 TOPICS

SUBJECT/WORD INDEX TO THE DARPA FY2002.2 TOPICS

SB022-022 **TITLE**: Induced Local EMP and Secondary THz Radiation in Sensor Window Materials from Intense Femtosecond Pulses at Long Range

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Exploit observed novel phenomena of intense femtosecond pulse propagation over tens of kilometer range in air and the associated properties of self-focusing, plasma generation, and materials damage for effective sensor and guidance and control countermeasures.

DESCRIPTION: Short laser pulses, < 200 fsec, from a Ti-sapphire laser, =800 nm, and of sufficient peak power per pulse, P, P>Pc, Pc = 6GW, are observed to propagate to at least 12 km in air [1], and spectrally broaden, due to self-phase modulation, over most of the visible spectrum (340nm-2000nm) [2]. In addition, local electromagnetic pulse (EMP) is observed at self-focus [3]. Also, materials surface damage is observed [4] when a glass plate is inserted at the focus, and is characterized by sharp ring structure due to oblation of material transversally and longitudinally at the surface, strongly suggestive of the projection pattern of the pulse in spatial intensity profile. Experimental and theoretical evidence indicates that the self-focus can be controlled to the target location. Possibilities are that controlled induced local EMP can neutralize sensor performance and perhaps that of guidance and control as well. Oblation at the surface is expected to generate local broadband secondary radiation centered at THz that could affect sensor performance and other electronic chip and circuit activity.

PHASE I: Based on physical models demonstrate the feasibility of generating efficient local EMP in air and secondary radiation in solid materials by intense femtosecond laser pulses. Describe in detail the underlying physical mechanism and its dependence on initial laser pulse and material parameters.

PHASE II: Design and demonstrate femtosecond laser system using focused geometry on a laboratory scale to induce and measure plasma generated EMP. Using the same laboratory system demonstrate surface damage pattern at the focus for glass and silicon (Si) and detect corresponding secondary radiation and determine central frequency and bandwidth, as well as spectral distribution. Measure and analyze the EMP signal in terms of total electromagnetic energy, peak field amplitude, power spectrum, and spatial distribution of the plasma and induced radiation. Measure and characterize the damage profile for ordinary glass, fused quartz, silicon, and germanium. Determine energy, range, distribution, and spectral distribution of the secondary radiation.

PHASE III DUAL-USE APPLICATIONS: The technology developed under this SBIR can be used commercially for remote sensing, novel broadband Laser Imaging Detection and Ranging (LIDAR) for remote detection and discrimination of atmospheric pollutants, controlled lightening discharge, and guide star applications.

REFERENCES:
1. L. Worste, C. Wedekind, H. Wille, P. Rairoux, B. Stein, S. Nikdov, C. Werner, S. Niedermeier, F. Ronneberger, H. Schillinger, and R. Sauerbrey, Laser Optoelektronik 29, 51 (1997).
2. N. Akozbek, M. Scalora, C. M. Bowden, and C. L. Chin, Optics Comm. 191, 353 (2001).
3. A. Proulx, A. Talebpour, S. Petit, and C. L. Chin, Optics Comm. 174, 305 (2000).
4. S. L. Chin, N. Akozbek, A. Proulx, S. Petit, and C. M. Bowden, Optics Comm. 188, 181 (2001).

KEYWORDS: Intense Femtosecond Pulse, Electro-magnetic Pulse, Self-focusing, Plasma Generation.

SB022-023 **TITLE**: Reducing/Eliminating Tuning of Microwave LC Filters

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Determine the optimum means of tuning or eliminating tuning for a variety of high frequency filter configurations during the manufacturing process. This technology will benefit Future Combat System missiles and other microwave and communications users including commercial users.

DESCRIPTION: Microwave technology is rapidly advancing to the point where commercialization at higher frequencies will soon be done on a wide scale. Filters are used extensively in communication and radar systems. During assembly of these complex filters, a labor-intensive method of tuning is usually used to obtain conformance with subsystem specifications. These manual methods of tuning can cost hundreds of dollars per filter. A previous investigation proved automated tuning methods could be developed to lower the tuning time and cost for quasi-lumped inductor/capacitor (LC) bandpass filters for a missile system. Reference 1 documents a prototype method that used material removal from planar capacitors by mechanical milling to tune a filter. The method demonstrated that a particular filter configuration required to be tuned only one time, versus numerous iterations when manually tuned. All subsequent filters of the same configuration could be etched to the same dimensions as the tuned filter. It is highly desirable to build on the initial study and determine the extent to which tuning can be improved or even eliminated for a variety of filter configurations. This topic aims to determine the limits of tuning by material removal using various means such as mechanical milling, laser, and other non-chemical means. Investigation is also needed to determine the extent to which higher frequency (including millimeter-wave) filters, other common bandpass filters (including side-coupled half-wave resonator, short-circuited quarter-wave stub, and interdigital), low pass filters, high pass filters, band reject filters, and matching circuits can be tuned more efficiently. Work is also needed to determine if some tuning can be eliminated entirely via more accurate models and designs, better materials, more repeatable material properties, and more controlled manufacturing processes.

PHASE I: Perform a "Design for Assembly and Tuning" study to determine filter configurations, which show the greatest potential for ease of assembly and tuning. Investigate filter-tuning processes to include material removal. These processes should cause minimal substrate changes when tuning. Identify readily available and developmental equipment for tuning filters and potential substrate materials. Fabricate a group of filters in the C and X bands and tune by various methods while tracking filter performance parameters such as passband, insertion loss, ripple, and rejection. Based on information acquired through fabrication/tuning, down select the tuning processes deemed to have the most potential with sufficiently low risk to permit development of a stable tuning process by the end of Phase II. Device performance, material costs, processing costs, and expected yields and scrap rates should be considered in the down select.

PHASE II: Develop a filter tuning station which will produce microwave LC and planar transmission line filters which achieve high performance at low cost. Investigate potential for determining precise filter physical configuration, which leads to the possibility of eliminating tuning. Investigate the possibility of using tuning in conjunction with commercially available filter design software to investigate the possibility of empirically determining unknowns such as parasitic effects. Perform tests to determine the tolerances that are required in terms of the substrate properties that are needed for various frequencies and the sensitivity of the tuning to substrate changes. Any substrate changes should be investigated to determine the degree to which substrate changes are tolerable. Design and fabricate various filter types at different microwave frequencies for tuning. Investigate ability to tune filters mounted on both hard and soft substrates. Develop a matured technique of tuning to encourage third party interest in further development and commercialization.

PHASE III DUAL USE APPLICATIONS: A Phase III effort will permit further enhancement of the capabilities of the prototype tuning equipment and processes and permit more complex filters to be designed and tuned for comparison to filters tuned under previous work. The potential market for low cost, easily tuned LC filters is huge. Because of the wide frequency range and wide choice of filter-response characteristics obtainable using lumped-element filters and their near approximation with quasi-lumped planar transmission line filters, these types of filters are used in virtually every variety of commercial and military communication and radar systems. Applications abound in the consumer, telecom, computer, and automotive industries, as well as the military. Commercial applications include computer and communications particularly Local Multipoint-Distribution Systems (LMDS), Direct Broadcast Satellite (DBS), and Intelligent Vehicle Highway Systems (IVHS). Military applications of the developed technology are numerous, aiding in the production of fire control radars, radar guided smart weapons, and communications systems.

REFERENCES:
1. John E. Reinhardt, Andrew V. Fogle, and Donald E. Dunstone, "Automated Process Cuts Filter Tuning Time From Hours to Minutes," Microwaves & RF, June 2001, pp. 103-104.
2. Charles A. Harper, Editor, Passive Electronic Component Handbook, 2nd Edition, McGraw-Hill, New York 1997, pp. 552-560.

KEYWORDS: Tuning of Microwave Filters, Design for Tuning.

SB022-024 **TITLE**: <u>Design of Mobile, Wireless (Ad Hoc) Networks Using Smart Antennas</u>

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: The design, evaluation and prototype implementation of medium access and networking protocols suitable for mobile, wireless (ad hoc) networks that can operate with directional antennas, and the evaluation of the performance of such protocols in networks as they are scaled.

DESCRIPTION: Smart (beamforming) antennas have the potential to provide substantial increases in the capacity of mobile, wireless (ad hoc) networks. When using omni-directional antennas, there is a tradeoff between the transmit power of a radio and its capacity to interfere with other simultaneous transmissions. This tradeoff imposes fundamental limits on the capacity of wireless networks [Gupta, Kumar 2000]. Directional antennas have the potential to increase transmit power without simultaneously increasing interference by limiting the direction in which the increased power is radiated. However, a number of questions need to be addressed before it will be feasible to use directional antennas in mobile, wireless (ad hoc) networks. A significant question is the design of appropriate media access control (MAC) and network layer routing protocols that can exploit the characteristics of the emerging class of beamforming antennas to improve the capacity and latency of mobile ad hoc networks. The protocols must be designed both to exploit the advantages of and to overcome the unique challenges presented by beamforming antennas: for instance, whereas narrower beamwidths of beamforming antennas reduce interference they also make neighbor discovery and contention avoidance more challenging, particularly in mobile networks.

PHASE I: Design and simulation of MAC/network protocols to effectively use smart antennas.

PHASE II: Prototype implementation and demonstration of benefits of such protocols, and identification of scenarios where the use of these protocols is expected to be beneficial, including addressing scalability in terms of the number of nodes, geographic area, and user traffic.

PHASE III DUAL USE APPLICATIONS: The Future Combat Systems program is considering the use of smart antennas for vehicular applications. The commercial use of smart antennas in cellular and community access networks is growing. MAC and network protocols that take advantage of the advantages of smart antennas are needed.

REFERENCES:
1. P. Gupta and P.R. Kumar. The Capacity of wireless networks; IEEE Transactions on Information Theory, VOL IT-46: 2; pp 388-404; March 2000.

KEYWORDS: Mobile, Wireless (Ad Hoc) Networks, Modeling and Simulation, Smart Antennas.

SB022-025 **TITLE**: Piloting Technologies for Conceptual High Speed Submersibles

TECHNOLOGY AREAS: Information Systems, Ground/Sea Vehicles, Sensors, Electronics, Battlespace, Human Systems

OBJECTIVE: Develop highly automated piloting and display technologies for a conceptual high speed, manned, “fighter-like” submersible capable of operations in littoral environments.

DESCRIPTION: The Department of Defense is pursuing innovative underwater propulsion technologies that in the future might be capable of supporting follow-on development of small underwater fighter-like vehicles. Such units would conceptually be capable of high-speed offensive military actions in littoral environments as both a counter to the asymmetric threat posed by Air Independent Propulsion (AIP) submarines and as an enabler of maritime forces’ ability to project power ashore. In the event that such submersibles can be developed based on current propulsion development efforts, they would require a revolutionary approach to existing submersible piloting systems. The piloting system would have to be able to guide the submersible along desired mission profiles using inputs from organic navigation sensors (sonar, E/O, etc.); provide safe passage at top speed around potential obstacles without operator intervention; and extract information for display from onboard subsystems required by the operator to ensure mission success. Such a submersible would require several degrees of autonomy coupled to situational awareness displays that would be capable of clear representations of the known tactical panorama and situation, as well as be capable of depicting/characterizing that which is uncertain. Technology is needed that will integrate and couple onboard information databases; organic sensor information; operator commands; guidance, navigation, and control components into a real-time piloting and display system that addresses anti-submarine warfare (ASW), anti-surface ship warfare (ASUW), Strike, and Indications & Warnings (I&W) littoral mission requirements. The conceptual submersible vehicle’s sensors would be the eyes and ears providing input data for the situational awareness displays that must be fused with onboard bathymetric databases, environmental models, and sensor models to create a synthetic tactical environment to orient the operator. Existing information fusion techniques would need to be integrated with innovative display technology that can be rapidly comprehended by a trained operator in order to minimize tactical uncertainty. Psychophysical effects associated with confined, subsurface operations and environments must be considered.

PHASE I: Develop a conceptual design for an advanced “cockpit” for a conceptual fighter-like submersible that includes interfaces with organic sensors (sonar, lidar, inertial), operator commands, and the vehicle control subsystem. Identify key piloting technologies needed to implement an actual system.

PHASE II: Develop a prototype cockpit for a conceptual undersea fighter-like vehicle that includes advanced control devices and innovative display technologies. To control cost and focus on the advanced control devices and display technologies, the interface to the organic sensors and control system shall be simulated at the information level vice data level.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR may be used in automated vehicles, UAVs, games, training devices, and in undersea simulations.

KEYWORDS: Control System, Display, Navigation, Cockpit, Submersible, Sensor, Sonar, Simulation.

SB022-026 **TITLE**: Forward Looking Collision Avoidance and Sub-Bottom Sensor for Conceptual High Speed Submersibles

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop a highly automated sensor for detecting obstacles (moving and stationary) and mine like objects in the water column and bottom/sub-bottom for employment on a conceptual high speed manned, “fighter-like” submersible that would be capable of operations in littoral environments.

DESCRIPTION: The Department of Defense is pursuing innovative underwater propulsion technologies that in the future might be capable of supporting follow-on development of small underwater fighter-like vehicles. Such units would conceptually be capable of high-speed offensive military actions in littoral environments as both a counter to the asymmetric threat posed by Air Independent Propulsion (AIP) submarines and as an enabler of maritime forces’ ability to project power ashore. In the event that such submersibles can be developed based on current propulsion development efforts, they would require a compact sensor capable of detecting and avoiding obstacles (moving and stationary) and mine like objects while traveling at high speeds. Existing torpedo sensors are designed to operate in equivalent speed regimes, but are not capable of detecting buried mine-like objects. Recent advances in broadband parametric sensors and squint-sidescan sensors may enable the development of a real time system that could display a 3-D presentation of the tactical panorama and situation in front of the submersible. The presentation must be capable of rapid comprehension by a trained operator and also be capable of being more rigorously processed if relayed to another naval unit with more advanced processing equipment not able to be located on the conceptual submersible.

PHASE I: Develop a design for an advanced compact forward-looking sensor for a conceptual fighter-like submersible that detects and displays obstacles (moving and stationary, bottom and surface features) and mine-like objects. The presentation must be capable of rapid comprehension by a trained operator. The design should address automated detection and classification algorithms that will be employed.

PHASE II: Develop and test a prototype compact forward looking sensor based on the design developed in Phase I.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR may be used in commercial undersea surveys and explorations.

REFERENCES:
1. Loggins, Chester D., "A Comparison of Forward-Looking Sensor Design Alternatives," Sonatech, Inc., MTS Report 933957.
2. Ruiz, I.T. et al, "AUV Navigation using a Forward Looking Sensor," Unmanned Underwater Vehicle Symposium, Newport RI, April 2000.

KEYWORDS: Sensor, Sensor, Doppler, Processing.

SB022-027 **TITLE**: Hubrid Hull Forms for Conceptual High Speed Submersibles

TECHNOLOGY AREAS: Ground/Sea Vehicles

OBJECTIVE: Develop a hybrid hull form that provides for external stores and reduced friction drag offering significant payload and speed advantages for a conceptual high-speed "fighter-like" submersible capable of operations in littoral environments.

DESCRIPTION: The Department of Defense is pursuing innovative underwater propulsion technologies that in the future might be capable of supporting follow-on development of small underwater fighter-like vehicles. Such units would conceptually be capable of high-speed offensive military actions in littoral environments as both a counter to the asymmetric threat posed by Air Independent Propulsion (AIP) submarines and as an enabler of maritime forces' ability to project power ashore. In the event that such submersibles can be developed based on current propulsion development efforts, they would require the capability of carrying a variety of sensor payloads and weapons tailored for specific missions. Aircraft have addressed this requirement through the use of pylons under the wing and fuselage. Such concepts introduce unique stress and drag issues when applied to a conceptual high-speed submersible. Additionally, some missions might require extended transits to the operating area that could be more efficiently traversed on the surface. Recent advances in lifting bodies may enable extremely high speeds on the surface by reducing the frictional drag. These concepts need to be explored and modeled using computational fluid dynamics (CFD) and other analysis tools to determine the feasibility of hybrid hull forms for such a conceptual high-speed submersible.

PHASE I: Develop multiple concepts and conduct preliminary analysis of hybrid hull forms for enabling a conceptual small, compact high speed submersible to carry a diverse set of "modular" weapons and sensors and also enable high speed energy efficient surface transits to extend the radius of action of the submersible.

PHASE II: Conduct CFD and other analysis on the most promising design concepts identified in Phase I. Build a scaled prototype and conduct hydrodynamic testing. (Note: If hydrodynamic testing is proposed to be performed at a government facility such as the Naval Surface Warfare Center Carderock Division test tank facility, all cost associated with the government's involvement must be identified as no cost to the SBIR contract and cannot be paid for with SBIR funds.)

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR may be useful and applicable in commercial small craft designs. The lifting body technology should have wide commercial applicability.

REFERENCES:

1. Granville, P.S., "Geometrical Characteristics of Streamlined Shapes," NSRDC Report 2962, March 1969.
2. Neumann, B.J., "Optimum Shaping For Axisymmetric Submersibles with Turbulent Boundary Layers and BLC Afterbodies," DTNSRDC-83/055.
3. Hess, J.L., "On the Problem of Shaping An Axisymmetric Body for Minimum Drag in Incompressible Flow," McDonnell-Douglas Corp Report MDCJ6791, Jan 1975.
4. Pashin, V., "Novel Hydrodynamic Concepts of Fast Vessels with Enhanced Seakeeping Performance," FAST'99 Conference, Seattle, Washington, Sep 1999.

KEYWORDS: Lifting Body, Hydrodynamics, CFD, Hull.

SB022-028 **TITLE**: Radio Propagation Prediction Software for Complex Mixed Path Physical Channels

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics, Battlespace

OBJECTIVE: Develop a very fast and highly accurate radio propagation model to support Communication and Information Warfare systems. This radio propagation model must encompass diverse types of propagation paths including long distances in rural terrain and urban areas. The physics based models must be capable of incorporating a limited number of available measurements for accuracy improvements. The model must include a wide range of frequencies encompassing all military communication systems. The development of this model will lead to a new radio propagation prediction capability that responds quickly to produce predictions for complex radio propagation paths over diverse geographic regions from digital terrain and features data.

DESCRIPTION: Modern radio communication systems make use of various bandwidths of radio spectrum in both digital and analog systems. A single propagation model that is applicable over a wide range of frequencies (50 MHz-100 GHz) and for communication channels including large distances over mixed paths that may simultaneously include irregular terrain with foliage, urban areas, and urban indoor-outdoor and even indoor-indoor paths is necessary to accommodate modern scenarios. These radio channels may utilize many different types of antennas mounted on a variety of platforms ranging from the individual warfighter to transport vehicles. The antenna height may vary from ground level to rooftop to airborne to satellite. Warfighters may be prone or vertical, or nearby or inside buildings. These factors, in addition to terrain variations, foliage, and building geometries and materials, have significant effects on radio communication channel reliability. While all these factors my affect the reliability of the radio channel, they are not accurately included in existing radio propagation channel prediction models. This requires efficient pre-processing of the available terrain and building information, fast but accurate analysis of the antenna performance and the electromagnetic interactions of the radio signals with the intervening terrain and structures, and presentation of the channel performance predictions in a format useful to mission planners and controllers. The goal is to automate and accelerate the entire radio channel performance prediction process starting from the available terrain and building information through selection of transmitter/receiver antenna types and locations (including both few-to-few predictions for wireless network planning and predictions for large coverage areas) to the presentation of predicted radio channel performance parameters.

PHASE I: Investigate methods for making mixed path radio propagation predictions. First consider paths simultaneously involving irregular terrain (with foliage) and building features. Perform validation checks of the proposed prediction methods and assess accuracy. Investigate methods for using a limited number of measurements to "tune" the physics-based models to improve accuracy.

PHASE II: Extend Phase I irregular terrain and building features mixed path model to higher and lower frequencies by including effects of ground wave and diffuse scattering. Couple ray-based models with other models, such as Parabolic Equation, to include additional mixed path situations. Automate the pre-processing of digital terrain elevation data (DTED), foliage data, and building geometry data for use by the propagation models. Investigate methods for estimating missing information, such as building materials or interior building structures. Fully implement methods for 'tuning' the results using a limited number of measurements.

PHASE III DUAL USE APPLICATIONS: Incorporate the radio channel model into existing radio propagation software tools. Incorporate databases of DTED, urban features, and communication equipment including antennas. Refine software displays to aid in decision-making process. Demonstrate utility in war game simulations and exercises. The diverse channel propagation model will have application to law enforcement communication planning and to a wide variety of wireless communication systems.

REFERENCES:
1. Radio Propagation for Modern Wireless Systems, H. Bertoni, Prentice Hall PTR; ISBN 0130263737.
2. Antennas and Propagation for Wireless Communication Systems, Simon R. Saunders, John Wiley & Sons; ISBN 0471986097.
3. The Mobile Radio Propagation Channel, 2nd Edition, J. David Parsons, John Wiley & Sons; ISBN 047198857X.

KEYWORDS: Radio Frequency, RF Wireless Networks, Radio Propagation.

SB022-029 **TITLE**: Improved Information Extraction Using Prior Knowledge to Satisfy Multiple Objectives

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Improve information extraction by simultaneously achieving multiple processing objectives, such as super resolution, suppression of non-stationary interference, and removal of high level clutter, using prior knowledge or estimated state conditions.

DESCRIPTION: DOD employs a variety of acoustic, seismic, optical and electromagnetic sensors. The signal processing that extracts militarily useful information from sensor data has been developed, often independently, in such contexts as inverse theory, information theory, imaging, beamforming, filtering, detection theory, and estimation theory. Important advances in signal processing have been made in addressing specific issues in particular contexts and work is ongoing to address such state-of-the-art issues known to affect system performance as: incorporation of prior knowledge; adaptivity; physics-based processing; resolution beyond the Rayleigh limit; sensor fusion at a coherent processing level; mitigation of non-Gaussian, non-stationary and coherent interference; multipath propagation; and the removal of constraints on bandwidth, waveform, geometry, and motions of sensor, target or medium (space-time diversity). The need exists for a unified theoretical framework that simultaneously addresses multiple issues that affect system performance. This framework would provide, for example: an advanced sonar processor that simultaneously provides both super resolution and adaptive suppression of non-stationary, frequency-dependent interference in a multipath, littoral environment; or, a clutter- and jam-resistant synthetic aperture radar that employs diversity waveforms, provides super resolution, and is unconstrained by platform maneuvers. Such a unified theoretical framework can provide a globally optimum solution that is superior to solutions obtained by independently addressing each performance limiting issue and then attempting to combine or concatenate the resulting processors.

PHASE I: Describe the theoretical basis for a signal processor that is capable of simultaneously satisfying the multiple performance objectives of as many as possible of the demonstrations described in Phase II and Phase III. Select one of the potential Phase II demonstrations and validate the theoretical predictions of improved performance using computer simulations.

PHASE II: Applying the basic scientific theory to field data, demonstrate feasibility of: 1) improved submarine detection in the presence of multiple, moving, interference sources in shallow water (non-stationary, non-Gaussian interference) by super resolution of interfering sources employing fusion of radar and sonar sensor data and the incorporation of environmental information at the level of coherent signal processing, or 2) improved acoustic synthetic aperture imaging of mines by super resolution of high level clutter in the presence of shallow water multipath, or 3) super resolution of Fourier Transform Infra Red (FTIR) absorption or transmission spectra for improved detection of chemical species by incorporating chemical bond characteristics as prior information, or 4) improved synthetic aperture radar that simultaneously reduces mainlobe width and sidelobe levels, rejects clutter, images non-point scatterers, reduces the effects of colored signal-independent background noise, and allows system operation with waveform diversity sufficient to mitigate jamming. Quantify performance improvements over existing systems and algorithms.

PHASE III DUAL USE APPLICATIONS: Demonstrate artifact-free x-ray Computer Aided Tomography (CAT) scans of soft tissue located in the vicinity of inoperable shrapnel by incorporating material characteristics as prior knowledge. Demonstrate super resolution in x-ray tomography by fusion with Magnetic Resonance Imaging (MRI) sensor information at the level of coherent processing.

This topic aims to exploit basic research results that are useful across a variety of applications, including geophysical exploration, undersea warfare (anti-submarine warfare (ASW), mine warfare, swimmer defense), radar (surveillance, Moving Target Indicator (MTI), Synthetic Aperture Radar (SAR), Inverse Synthetic Aperture Radar (ISAR)), hyperspectral imaging, communications, non-destructive testing, etc.

Specific Phase III military applications of the technology:
Adaptive, super-resolution ASW sonar in non-stationary littoral environments,
Adaptive, sub-pixel, hyperspectral analysis,
Fusion at a coherent processing level of multiple sensing modes, such as radar and acoustics or infrared (IR) and radar.

Specific Commercial applications of the technology:
Fusion at a coherent processing level of multiple medical imaging modes such as x-ray tomography and magnetic resonance imaging.
Adaptive, high-resolution, x-ray tomographic imaging of soft tissue located near high-density material (e.g., removal of artifacts from soft tissue CAT scans of military personnel carrying inoperable shrapnel).
Fusion at a coherent processing level of multiple geophysical sensing modes, such as seismic, surface-magnetic, and borehole data.

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1. Backus, Bayesian Inference in Geomagnetism, Geophys. J. R. astr. Soc. 92, 125-142 (1988).
2. D. Rabideau, Clutter and Jammer Multipath Cancellation in Airborne Adaptive Radar, IEEE Trans AES 36, 565-583 (2000).
3. G. Zweig and B. Wohlberg, Inverse Synthetic Aperture Radar (ISAR) Imaging and Crystal Structure Determination from Extended X-ray Absorption Fine-Structure (EXAFS) Data Using a Super-Resolution Fast Fourier Transform, Proceedings of the Tenth IEEE Workshop on Statistical Signal and Array Processing, Pages 458-462 (2000).
4. S. Luttrell, Bayesian Autofocus/Super-Resolution Theory, IEE Colloquium on Role of Image Processing in Defense and Military Electronics, Pages 1/1-1/6 (1990).
5. S. Bhattacharjee and M. Sundareshan, Modeling and Extrapolation of Prior Scene Information for Set Theoretic Restoration and Super-Resolution of Diffraction-Limited Images, Proceedings of 2000 International Conference on Image Processing, Vol 2, Pages 347-350 (2000).

KEYWORDS: Remote Sensing; Signal Processing; Prior Information; Adaptivity; Physics-Based Processing; Super Resolution; Fusion; Interference; Multipath.

SB022-030 **TITLE**: Real-Time Assessment of Student State

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: The revolution in military affairs within the Services and in joint warfare will require a parallel revolution in training affairs. The complexity of future warfare, its fluid nature and the frequent isolation of the future American warrior will make a qualitative change in what each service member and military unit must be trained to do. Neither school-house-based training nor the current, mostly passive, computer/web-based training approaches are likely to succeed in insuring that competence will be at the point of use when it is needed. Something new is required. It will include elements that make the following training approaches work: human tutoring, computer gaming, Combat Training Center (CTC) training, and collaborative learning.

DESCRIPTION: A key element missing in current computer-mediated training is that, unlike a human tutor, the computer does not currently build a multi-dimensional, real-time model of the state of the student and then change its teaching behavior based upon that assessment. Fundamental to the creation of such a model is real-time measurement of the state of the student. The multi-dimensional state vector might include information about the student's physiological state, psychological state and knowledge level. Measurement technologies might include: keyboard tracking; voice measurements; eye tracking; generation and matching of knowledge maps; remote detection of such parameters as skin temperature, heart rate, respiration, eye-blinking; infra red sensing of the outer layers of the brain; and others. This project will develop one or more assessment technologies and apply them to a military training need. Although this is primarily a project to develop measurement tools, the offerer must demonstrate an understanding of how real-time assessment of their chosen variable(s) might be used to enhance learning.

PHASE I: Phase I will determine the feasibility of creating a student state measurement system that assess one or more of the physiological, psychological or knowledge elements using one or more measurement modalities. Although the more elements of the student state that can be measured, the better, a proposal offering a clear pathway to the use of a single sensing modality on one component of the student state will be preferred to one that offers to choose, at some later time, from a broad range of less well-defined concepts. The final state-of-the student sensing system must be cheap, portable; convenient for the student to use and be based upon processing by common mass-market computer hardware (PC or Macintosh) otherwise it will not be used by the military or civilian training market. A clear understanding of how the measurement technology will be assessed and validated is also required.

PHASE II: Phase II will build prototype instrument(s), validate the assessment technology and integrate them into one or more military training application.

PHASE III DUAL USE APPLICATIONS: The military world is not alone in changing so rapidly that current training approaches can not keep up; everything from computer networks to automobiles suffer from this problem. The new training systems will be enabled by real-time student measurement and modeling technologies will be applicable throughout the information-dominated economy.

REFERENCES:
1. Training Superiority and Training Surprise, Defense Science Board Task Force Report February 2001.

KEYWORDS: Training, Knowledge Maps, IR Sensing, Eye-Tracking, Student Modeling, Intelligent Tutoring Systems, Autotutors, Tactical Decision Aids.

SB022-031 **TITLE**: Ad Hoc Human Information Nets for Asymmetric Threat Surveillance

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop and demonstrate novel messaging, control and information service technologies, to task, collect and manage information obtained from large numbers of individuals assembled as an ad hoc Humint (Human Information) network, using wireless communication fabrics and information appliances.

DESCRIPTION: The nature of the asymmetric threat, illustrated by recent events, demonstrates the great difficulty of conducting sustained and comprehensive surveillance of organizations comprising loosely-coupled networks of highly motivated individuals, dispersed over large geographic areas, who collectively are involved in activities that have enormous disruptive potential to the national security. While technical means of surveillance have significant potential to address this threat once it is identified and localized, these resources cannot effectively conduct search, detection and localization operations against such a scattered and amorphous threat. Similarly, the use of professional human assets to collect intelligence is limited both by their number and their individual levels of expertise to focus on only relatively few targets within well-defined areas of interest. This effort recognizes the opportunity provided by emerging communication fabrics and information appliances for enabling large numbers of "lay" individuals to be rapidly assembled as an ad hoc human information (Humint) network to collect time sensitive, critical information regarding the activities of a potential threat. This Humint network could be applied to provide deep and comprehensive surveillance of a threat across multiple dimensions – geographic location, subject matter, industry, supply chain, transportation network, etc. This topic seeks to develop messaging, control and information services technologies specific to tasking, collecting and managing information obtained from extremely large numbers of ad hoc Humint agents. Novel techniques for discovering, defining and addressing the members of an ad hoc network, whose numbers may range in the 1,000's to 10,000's; disseminating messages to all or only part of the network with tasking regarding a particular information collection or surveillance objective; prioritizing, aggregating and synthesizing message streams, which may range in the 10,000's to 100,000's; and managing/facilitating interaction and information sharing among members of the network are sought. The messaging, control and information services technologies developed should assume the use of emerging wireless communication infrastructures and information appliances (e.g., SMS/web-enabled cell phones, PDAs, two-way paging/e-mail devices (e.g., Blackberry), etc.)

PHASE I: Conduct a feasibility study and develop a messaging network architecture for implementing an ad hoc human information network. The Phase I effort will develop a detailed approach and schedule for developing and deploying a prototype system in Phase II.

PHASE II: Develop and deploy a prototype ad hoc human information network. Conduct tests within multiple major metropolitan service areas involving live participants cooperating on a simulated information-gathering task to demonstrate the system's ability to assemble and address the network "on the fly", distribute tasking and collect/prioritize/aggregate message streams.

PHASE III DUAL USE APPLICATIONS: The resulting prototype system will serve as the basis for numerous commercial systems. Applications include security, transportation and public safety, intelligence, entertainment, training, advertising and promotions in government, military, and commercial venues.

KEYWORDS: Ad hoc Networks, Messaging Systems, Content Management, Wireless Communications.

SB022-032 **TITLE**: Single View 3D Face Recognition Technology Development

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop technology to acquire and process 3-Dimensional views of human faces using a single sensor.

DESCRIPTION: Face recognition and identification capabilities are severely limited by variations in pose. Emerging research indicates that using special techniques combined with 3D images of subjects may significantly enhance face recognition performance. 3D facial image acquisition, however, is cumbersome and time consuming, requiring multiple sensors, complex apparatus, and cooperative subjects. These characteristics render the collection and use of such imagery unsuitable for most military and civilian real-world applications. Single view acquisition of 3D facial images represents breakthrough technology with respect to ease of application within existing security infrastructures and the potential to significantly enhance face recognition performance.

PHASE I: Conduct initial research in a lab environment to determine the efficacy of collecting 3D facial images using a single sensor. Establish baseline performance characteristics associated with single view 3D facial image collection. Establish and archive a single view 3D facial image database.

PHASE II: Extend Phase I research into a more operational environment – increased range with variations in illumination. Establish baseline performance characteristics associated with this environment to include variations in both range and illumination. Establish and archive a single view 3D facial image database associated with the operational environment.

PHASE III DUAL USE APPLICATIONS: Single View 3D Face Recognition technology developed under this SBIR will have immediate impact upon both military and commercial face recognition capabilities which support force protection, a wide variety of standard military and special operations, airport security, key-facility security and Homeland Defense.

KEYWORDS: 3D Face Imaging; Face Recognition, Human Identification.

SB022-033 **TITLE**: Personnel and Vehicular Monitoring and Tracking at a Distance

TECHNOLOGY AREAS: Information Systems, Sensors

OBJECTIVE: Develop 3D biometric technologies as part of a multi-modal system to detect, track and recognize humans and vehicles at a distance to support early warning, force protection, and operations against terrorist, criminal, and other human based threats.

DESCRIPTION: The Department of Defense (DoD) is at a heightened state of awareness since the terrorist attack on September 11, 2001. Many military and civilian defense facilities need technology that will help them monitor and track potential terrorists before an attack takes place. Most existing identification systems use single sensor mechanisms that only work in fixed environments with static illumination using 2D technology that may not be totally reliable. Additionally, interpreting moving 2D images is often difficult, time consuming and expensive. In order to improve existing system capabilities and increase the ease and speed of interpretation, a more robust system is required. Fusion of 3D imaging, and inexpensive real time stereo vision processing with other biometrics modes, such as body dynamics, in a system will provide a more robust monitoring and tracking capability for moving people or vehicles when coupled with greater reliance on activity characterization than identification. The goal of the system is to track individual people or vehicles over extended areas without actually identifying them as a priori known entities, or needing to maintain continuous track on them at all times. By tracking entities through both space and time, using integrated tracking and identification techniques, the system will be capable of discerning both local and more global activities to detect suspicious behavior, and increase the likelihood that suspects are apprehended.

PHASE I: Fuse accurate, real-time, 3-dimensional imaging software that provides accurate distance measurements to reliably interpret a scene, with body dynamics tracking technology. Process moving object images at a minimum of 135 frames per second to increase robust tracking capabilities.

PHASE II: Combine resulting 3D imaging system with other biometric modes such as face recognition, infrared sensors, and remote iris scan.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be used in a broad range of military and civilian security applications where automatic surveillance and tracking are necessary. For example, the military Services could use it to better protect DoD facilities, while civilian applications range from protecting industrial facilities to airport security.

KEYWORDS: Sensors, Video, Surveillance, Object Tracking, Stereo Vision, 3D Tracking, Person Tracking, Head and Hand Tracking, CMOS Imaging.

SB022-034 **TITLE**: Scalable Heterogeneous Social Network Analysis

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop algorithms and associated data structures for analyzing social networks of large numbers of individuals who may be members of multiple, overlapping, structured organizations and who may be linked by multiple types of interactions.

DESCRIPTION: Terrorist networks consist of cells of individuals who communicate infrequently and who share minimally necessary information. It may be possible to recognize the existence, membership, structure and activities of these networks using techniques from social network analysis. Current algorithms typically handle networks consisting of only one type of individual with one type of link; do not recognize the possibility of multiple overlapping organizations; and do not have organizations with intermediate structures. Current techniques need to be specified as algorithms and data structures and extended to overcome these limitations. Combinations of ideas and expertise from the areas of social network analysis, graph theory, and algorithms and data structures are needed.

PHASE I: Design and develop algorithms and data structures for scalable social network analysis of large numbers of individuals who may be members of multiple, overlapping, structured organizations and who may be linked by multiple types of interactions.

PHASE II: Implement algorithms and data structures into a software package and evaluate against realistic data sets of size and characteristic typical of real problems.

PHASE III DUAL USE APPLICATIONS: Dual use applications would apply throughout large scale and informal human organizations. This includes not only corporations but also informal organizations, which have arisen as a result of the Internet.

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1. Artificial Intelligence and Link Analysis, Technical Report FS-98-01, AAAI Press, 1998. ISBN 1-57735-075-8.
2. Wellman, Barry and S.D. Berkowitz, 1997. Social Structures: A Network Approach. (updated edition) Greenwich, CT: JAI Press.
3. Wasserman, S. and K. Faust, 1994, Social Network Analysis. Cambridge: Cambridge University Press.

KEYWORDS: Link Analysis, Algorithms, Scalability, Graph Theory, Data Structures, Social Network Analysis.

SB022-035 **TITLE**: High Efficiency, Scalable, Parallel Processing Approaches for Multi-Sensor Data Fusion

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics, Battlespace

OBJECTIVE: Develop novel methodology to achieve high utilization for scalable parallel processing systems with maintainable distributed scalable multiprocessor efficiency in excess of 90%. Demonstrate for a data-rich multi-sensor fusion application showing the performance improvement over conventional methods.

DESCRIPTION: The proposed research and development shall provide the ability to implement scalable, parallel processing systems that maintain scalable processor efficiencies greater that 90%. For large processing challenges such as multi-sensor fusion of large data sets single processor implementations are insufficient. The solution to such processing challenges has been to attempt to implement parallel processing implementations that divide the processing load across a set of processors. This ideally would produce a linear increase in processing capability based on the number of processors utilized, however in implementation a corresponding linear increase in processing performance has not resulted. The overheads and inefficiencies of data and workload distribution lead to substantially less processing capability being applied than the processing potential available. In actual practice large parallel systems are successful if they obtain 10% of the operating potential of the processing elements and for challenging cases less than 1% efficiency may be obtained. The proposed research is to identify, develop, and demonstrate with a DoD relevant data rich, multi-sensor, processing intensive application a scalable parallel processing approach that will maintain efficiencies greater than 90% of multiprocessing system capabilities and is applicable to existing off-the-shelf processing clusters and massively parallel systems.

PHASE 1: Develop the methodology to provide greater than 90% multiprocessor efficiency for scalable, parallel processing systems. Demonstrate utilizing a parallel system of not less than 12 processing nodes for a relevant sensor data fusion example application showing the efficiency improvement over conventional methods.

PHASE II: Expand the methodology to be viable for a collection of commercial off-the-shelf (COTS) processors and demonstrate system linear scalability that is not degraded by increasingly larger data sets. The demonstration application shall be for a large-scale multi-sensor fusion application that requires, as a minimum, 90% efficiency. The physical system shall be composed of as a minimum 256 processing nodes.

PHASE III DUAL USE APPLICATIONS: The methodology developed under this topic would be applicable to any commercial application that requires or utilizes parallel processing; the methodology would be applicable to existing and future parallel processing implementations specifically including those utilizing commercial off-the-shelf processing components.

REFERENCES:
1. Culler, David and Singh, Jaswinder; Parallel Computer Architectures: A Hardware /Software Approach; Morgan Kaufmann; 1999; Library of Congress #QA76.58.C85; (Chapters 1, 7, and 11).
2. Hoosta, Seyed; Parallel Processing and Parallel Algorithms: Theory and Computation; Springer; 1999; Library of Congress #QA76.58.R66.
3. Koniges, Alice (Editor); Industrial Strength Parallel Computing; Morgan Kaufmann; 2000; Library of Congress #QA76.58.I483 (Chapter 21 – Figures 21.2 and 21.3).

KEYWORDS: Parallel Processing, Scalable Processing, Multi-Sensor Fusion, Processing Efficiency, COTS, Parallel Processing.

SB022-036 **TITLE**: Development of Predictive Algorithms for In Silico Drug Toxicity and Efficacy Assessment

TECHNOLOGY AREAS: Chemical/Bio Defense, Information Systems

OBJECTIVE: Develop algorithms and software tools to analyze, classify and predict the potential toxicity and efficacy of drug candidates, to be suitable for application to large databases of genomic and chemical data.

DESCRIPTION: Research and development leading to tools based on experimental data sets that enable the creation of software for predicting the potential in vivo effects of drug molecules in biological systems. Of particular interest are effects arising from chemical and biological agents and pathogens. Efforts should focus on data mining and/or computational modeling techniques to gain a more accurate assessment of drug efficacy and toxicity. This includes extraction of correlations and learning of structures of relationships among various data elements. Methods must be suitable for acting on heterogeneous databases containing micro array data, gene expression data, data on genomic networks, bioassay data, and protein-drug interaction data. Efforts may be based on the analysis of protein-drug interaction patterns across a wide-range of drugs, known toxic molecules and clinical research-stage chemicals. Efforts must develop algorithms, based on the information in the database, for classifying and predicting toxicity and efficacy of drug molecules. Methods should be scalable and extensible to handle heterogeneous databases of large sizes. Proposals must clearly define the features that form the basis for high-resolution classification. Efforts must also clearly define and implement the basis for validating and evaluating the performance of prediction algorithms, and this may include prediction of known effects or new experimental demonstrations. Interoperation of the software with the Bio-SPICE software being developed in the DARPA Bio-COMP Program is desired but not mandatory (see reference 5, below).

PHASE I: In detail, define a strategy for developing classification and predictive algorithms for drug toxicity and efficacy assessment. Identify the databases for algorithms development. Define and evaluate methods for validating the predictive capability of these algorithms for molecules of known human in vivo effects, and for new research molecules of unknown effects. Identify candidate experimental and algorithmic modeling approaches for implementation.

PHASE II: Refine, optimize and implement the selected approaches and scale-up for application to significant sets of drug candidates. Demonstrate the validation of predictive algorithms.

PHASE III DUAL USE APPLICATIONS: Develop and package the algorithmic models as a flexible software tool in a manner that provides high utility to end-users. Commercialize the resulting software tool.

REFERENCES:
1. Persidis, A. Data mining in Biotechnology. Nature Biotechnology 18: 237-238, 2000.
2. Myers, S. and Baker, A. Drug Discovery--An Operating Model For a New Era, Nature Biotechnology 19: 727-730, 2001.
3. Frawley, W., Piatetsky-Shapiro, G., and Matheus, C. Knowledge Discovery in Databases: An Overview. AI Magazine 13(3): 57-70, 1992.
4. Karp, P.D. Pathway Databases: A Case Study in Computational Symbolic Theories. Science 293: 2040-2044, 2001.
5. http://www.biospice.org.

KEYWORDS: Data Mining, Chemical Genomics, Genomic Networks, Drug Profiling.

SB022-037 **TITLE**: User-Defined Critics for Software Adaptation

TECHNOLOGY AREAS: Information Systems, Human Systems

OBJECTIVE: Develop software tools that allow users to define critics that adapt existing software to meet changing internal and environmental situations.

DESCRIPTION: The need for software that can adapt itself to changing situations based on user-defined criteria represents the next great challenge in software development. Existing software tends to be brittle and inflexible, requiring the coordinated efforts of usability experts, knowledge engineers, and software engineers to update programs. These updates are usually in the form of new product releases or patches. Software that allows users to define their needs and updates itself to meet those needs could substantially reduce the coding efforts required in rapidly evolving environments. One approach to solving the software adaptation problem is to endow software with the knowledge of its own inner-workings. Potentially, this "meta" or "reflective" knowledge would allow software to analyze and adapt itself as new situations are encountered. To capitalize on meta-knowledge, however, requires additional knowledge in the form of critics. Ideally, adaptation should correspond to a user's needs, which means that critics will need to understand and incorporate these needs. There is currently no effective way for users to define unforeseen situation-specific needs, nor is there a way to apply that information to adapt existing or future software. The development of tools that allow users to define critics would go a long way towards the goal of flexible software.

PHASE I: Design software technology for defining critics that demonstrates the use of meta-knowledge and the ability to adapt software based on user needs.

PHASE II: Implement a prototype system that allows users from different domains to adapt software through user-defined critics.

PHASE III DUAL USE APPLICATIONS: This technology has potential uses in a wide range of military and commercial products. The technology could enhance any software system that requires frequent updates or varied specializations, e.g., military software systems (logistics, planning, or simulation) or commercial software (pharmaceutical R&D software, CAD/CAM, or Business Simulation).

REFERENCES:
1. Stroulia, E. & Goel, A.K. (1995) Functional Representation and Reasoning in Reflective Systems. Journal of Applied Intelligence, Special Issue on Functional Reasoning, 9(1):101-124.
2. Murdock, J.W. & Goel, A.K. (1998) A Functional Modeling Architecture for Reflective Agents, AAAI-98 workshop on Functional Modeling and Teleological Reasoning, Madison, WI, July, 1998.

KEYWORDS: Intelligent Systems, Adaptive Software, Reflection.

SB022-038 **TITLE**: TeraHertz Sources and Detectors for Sensing and Imaging Systems

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop portable systems that operate at TeraHertz (THz) frequencies (30 to 300 micron wavelengths) for biological and medical imaging, and for biological and chemical agent detection.

DESCRIPTION: The TeraHertz frequencies can be used for a wide range of sensing and imaging applications including medical diagnostics, and chemical and biological identification. The unique attributes of THz radiation include: (1) strong sensitivity to molecular absorption; (2) partial transparency through macroscopic solids for structural and medical imaging; and (3) high signal bandwidths and small size devices due to the short wavelengths (0.1 millimeter) compared to microwaves. The THz frequencies have been relatively unexplored because of technical barriers that may be overcome using novel device approaches. New developments in bandgap engineering permit THz signal generation and detection using intersubband transitions between states in quantum wells, or with high-speed heterojunction transistors. The Group III-V and IV materials are compatible with circuitry that can be utilized for control, modulation, and signal processing. The high efficiency and low power levels of novel devices may permit portable THz devices to be carried by personnel. The goals of this project are to investigate the suitability of THz frequency techniques to image biological and other systems, and to determine the additional information that may be provided that is complementary to other techniques such as near infrared techniques.

PHASE I: Demonstrate the feasibility of THz sources and detectors in semiconductor technology that are capable of being interfaced to Silicon Complementary Metal Oxide Semiconductor (Si CMOS) circuitry. Demonstrate a source and detector proof-of-concept system that can be used to image biological and chemical systems.

PHASE II: Design, fabricate and demonstrate a THz source/ detector system for imaging. Show how the THz system can be integrated into a portable imaging system.

PHASE III DUAL USE APPLICATIONS: The designs developed under this topic could be used for a wide range of commercial biological and chemical applications, including medical imaging and identification of chemical compounds in portable devices that operate at TeraHertz frequencies.

REFERENCES:
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2. Kolodzey, J. Silicon germanium alloy devices, in Hetero-Structures for High-Performance Devices, Colin Wood and Maurice H. Francombe, Academic Press, 2000.

KEYWORDS: TeraHertz Technology, Imaging, Sensing, Detection, Medical Diagnostics, Semiconductor materials and Devices.

SB022-039 **TITLE**: Dense Array EEG for Real-Time Cognitive State Detection

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop dense array electroencephalograph (EEG) for real-time analysis of human cognitive processing for real-time assessment of cognitive state for use in operational environments.

DESCRIPTION: Understanding how the human operator processes information in the modern digital environment, requires cognitive analysis tools and neuroimaging methods with millisecond temporal resolution. Imaging techniques such as Positron Emission Tomography (PET) and functional Magnetic Resonance Imaging (fMRI) provide essential anatomical information about the location of cognitive processes, but only on the order of minutes. These techniques are too slow to track the instantaneous neurophysiological processes involved in dynamic information processing. Currently available EEG arrays (32 channel) are not sufficient for the spatial precision needed to localize a particular brain function. Dense array (128+ channel) EEG provides the critical temporal resolution, and sufficient spatial resolution for the anatomical analysis of cortical activity. Development of this technology will permit us to distinguish between functional domains of cognitive processing (e.g. working memory vs. spatial recall) in real-time. Using these arrays, stimuli presented in the testing environment would be used to establish the neural correlates of the various modalities (spatial, auditory, tactile, and haptic) the moment they are presented. With millisecond accuracy and continuous monitoring, the operator's responses to the stimuli can be tracked, from planning (i.e. premotor frontal activity) through execution. Ultimately, access to this information in real-time would allow for interface designers to account for the current cognitive capacity of a particular operator into their displays and information delivery.

Development of this technology will also enable the correlation of brain activity (as measured by EEG) to hemodynamic measurement methods, which would contribute to resolution of the pervasive question in neuroimaging “does cortical blood flow accurately represent the activity of the brain?”

PHASE I: Demonstrate the feasibility of high density EEG through the designing and testing of appropriate technologies. Begin to investigate neural correlates of the sensory modalities in real-time using EEG arrays.

PHASE II: Continue investigating the neural correlates of sensory modalities using high density EEG. Identify an operational task that taxes certain aspects of the operator’s cognitive capacity (i.e. spatial working memory). Real-time augmentation/modulation of the operator’s environment based on activated functional domains.

PHASE III DUAL USE APPLICATIONS: EEG components can be used commercially for numerous medical applications.

REFERENCES:
1. Janata P. Brain electrical activity evoked by mental formation of auditory expectations and images. Brain Topogr 2001 Spring;13(3):169-93.
2. Murray MM, Foxe JJ, Higgins BA, Javitt DC, Schroeder CE. Visuo-spatial neural response interactions in early cortical processing during a simple reaction time task: a high-density electrical mapping study. Neuropsychologia. 2001;39(8):828-44.

KEYWORDS: Dense Array EEG, Real-Time Cognitive State Detection, Cognitive Capacity.

SB022-040 **TITLE**: Knowledge Acquisition for Level II/III Fusion

TECHNOLOGY AREAS: Information Systems, Human Systems

OBJECTIVE: Develop technology for acquiring uncertain relational knowledge from subject-matter experts, and demonstrate its application to the acquisition models of adversary behavior, intent, or organizational structure to support level II/III fusion.

DESCRIPTION: A principled treatment of uncertainty is essential to all fusion processing, to enable systematic scoring and comparison of hypotheses built from partial, noisy information. New representation languages have recently emerged that combine probabilistic and relational information at the type level [1]. These languages are well suited to encoding the models that Level II/III fusion requires—uncertain relational models of adversary behavior, intent, and organizational structure. This SBIR focuses on developing technology for knowledge acquisition in such languages. Knowledge acquisition has long been recognized as a bottleneck in the development of knowledge-based systems. Important recent advances in knowledge acquisition technology (e.g. [2]) are beginning to support acquisition of models in relatively expressive relational languages that include equality constraints at the type level. However, these languages do not support uncertainty. On the other hand, much research has been conducted in the acquisition of probabilistic knowledge, especially in the context of discrete Bayesian networks. However, Bayesian networks do not by themselves support representation of relational models. The work performed under this SBIR will develop innovative technology for acquisition of large probabilistic relational knowledge bases, to support development and maintenance of level II/III fusion systems. Research advances are required that synthesize insights from knowledge acquisition research in Bayesian networks and acquisition of non-probabilistic symbolic knowledge.

PHASE I: Develop algorithms and methodologies for the acquisition of probabilistic relational knowledge from subject-matter experts with little or no training in formal knowledge representation or probability theory.

PHASE II: Implement prototype software to acquire probabilistic relational knowledge. Validate the approach by using the prototype to acquire models of adversary behavior, intent, and/or organizational structure, and employing these models to solve a real-world level II or level III fusion problem.

PHASE III DUAL USE APPLICATIONS: Level II/III fusion has widespread application in military, intelligence, and civilian organizations. Applications of this technology include battlespace situation and threat assessment, early detection of indications and warnings of terrorist activity, interpretation of medical imagery, condition-based maintenance complex machinery, and interpretation of business intelligence. The technology developed under this SBIR will dramatically reduce the cost of developing and maintaining level II/III fusion systems.

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1. A. Pfeffer. Probabilistic Reasoning for Complex Systems. Ph.D. Dissertation, Stanford University, December 1999.
2. P. Clark, J. Thompson, K. Barker, B. Porter, V. Chaudhri, A. Rodriguez, J. Thomere, S. Mishra, Y. Gil, P. Hayes, T. Reichherzer. Knowledge Entry as the Graphical Assembly of Components. In Proc 1st Int Conf on Knowledge Capture (K-Cap'01), 2001.

KEYWORDS: Knowledge Acquisition, Bayesian Network, Probabilistic Relational Models, Level II Fusion, Level III Fusion, Knowledge Representation, Knowledge Base, Artificial Intelligence, Uncertain Reasoning, Symbolic Knowledge.

SB022-041 **TITLE**: Machine Detection of Operationally Significant Cognitive Events for C4ISR

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: A variety of modalities have been proposed for human computer interaction (HCI) such as eyeball tracking, gestures, tactile sensors etc. All these approaches rely upon a conscious attempt by the human to launch a query or provide an unambiguous instruction to the computer. In this SBIR we seek to explore the feasibility of expanding on HCI to include direct, automated sensing of cognitive function. As background information, in the scientific literature there have been a number of studies which demonstrate that portable, non invasive techniques, such as pupillary response, hemo-oxygenation, and evoked potential, can be employed to measure specified cognitive activities in controlled laboratory experiments. Examples include the onset of solution discovery in anagrams and scholastic aptitude rating (SAT) scores [1], medical imaging diagnosis [2], interpretation of symbology [3], and mental workload monitoring [4]. None of these activities have had the goal of, or have demonstrated the feasibility of measurement of operationally significant cognitive events. The purpose of this SBIR is two fold. Phase I is to prove the existence of a device, or conglomerate devices, which can be employed to provide reliable detection (as measured by receiver operating curve, or statistical power) of cognition events which would be of credible practical benefit in an operational context. The application of choice is left to the offeror, but must be drawn from the Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) arena. Examples would include target recognition by an image analyst, significant change in perceived threat condition by a commander, sudden insight regarding situational awareness of enemy intent by an intelligence analyst etc. The attempt is not to classify the cognitive event, merely to detect its occurrence in context. Military applications are numerous, and depend to a large extent on the robustness of the detection procedure. At the high end one can envision automated neural net training. Less fanciful perhaps, is “hands off” through-echelon command. In this application the command and control (C2) warfighters are cognitively “wired” during their task prosecution. Detection of significant cognitive events throughout the command chain triggers automatic situation updates, which are then relayed throughout the hierarchy. This would allow for unprecedented team cohesiveness during extremely stressing encounters where cessation of warfighter activity to provide status reports is unacceptable. In fact one can argue that the ability to provide manual status reports is inversely proportional to level of stress, and therefore the need to report is most acute precisely when the opportunity is most elusive.

DESCRIPTION: The first objective of the effort is to construct an experiment to demonstrate that there are data, observable in processes such as near infrared imaging, evoked potential response (EPR), or pupillary action, that correlate with cognitive events as reported by the subject. Domain experts must be selected for the experiments, and the stimulus must reflect in some credible fashion, albeit truncated, the complexities of a militarily realistic C4ISR task. The second objective is to build upon the experimental evidence to build a concept of operation, and a circumscribed feasibility demonstration, that the measurements are not only statistically meaningful but also practically useful. The successful offeror will need to define a single precise C4ISR task, a coherent, controlled experimental regime, operational concept of operations (CONOPS), and verifiable access to realistic C4ISR computer display data and domain expertise. Surrogates for deployable sensors, such as Functional Magnetic Resonance Imaging (fMRI) are allowable, provided tractability to a deployable objective system is offered. Because of the unique skill set required to execute this program creative teaming arrangements are encouraged as required.

PHASE I: Conduct an experiment to validate that operationally significant cognitive events can be captured in an autonomous fashion. Deliverables will include test plan, and a reduction of data collect, including assessment of type I and type II errors using established statistical procedures.

PHASE II: Use the statistical power measured in Phase I to construct a concept of operation. Conduct a scaled utility demonstration for a selected C4ISR task.

PHASE III DUAL USE APPLICATIONS: HCI is an area of intense interest due to the limited bandwidth of current approaches. If cognitive sensing can be shown to be sufficiently robust to provide C4ISR utility it will have dual use HCI applications for high risk teamwork such as deep sea diving (off shore oil exploration), astronautics (EVA), or criminology.

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KEYWORDS: Human Computer Interface, Cognitive Monitoring, Autonomic Observables of Cognition, Brain Imaging, Eye Tracking, Virtual Reality Computing.

SB022-042 **TITLE**: 3-D Modeling from Video

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Design and demonstrate techniques to reconstruct three-dimensional scene and object structure from an image sequence, freely taken by an ordinary video camera.

DESCRIPTION: Automatic acquisition of 3–D models of buildings, vehicles, and structures is in high demand for visualization, recognition, and mission-rehearsal systems. However, manual construction of such models takes far too long to be of practical use, and specialized sensors such as Interferometric Synthetic Aperture Radar (IFSAR) and Laser Induced Differential Absorption Radar (LIDAR) are not practical for many applications. The structure-from-motion problem has been long studied and much is known about 3-D constraints derivable from sequences of images in which point correspondences can be established. The processing power of commodity computers has now reached the point where it may be possible to develop practical 3-D modeling applications that exploit these results. Potential military applications of this technology include: automatic construction of detailed terrain models from airborne video cameras; automatic construction of 3–D models of building exteriors and interiors from hand–held video; rapid acquisition of 3–D models of vehicles for use in visualization and target recognition systems.

PHASE I: Perform implemented feasibility studies of key components of a system to build 3-D models from video. Evaluate accuracy, reliability, and flexibility attainable. Finalize design of prototype.

PHASE II: Build, demonstrate, and validate complete system.

PHASE III DUAL USE APPLICATIONS: Video cameras are inexpensive and universally available, but are used mainly to facilitate the capture and viewing of motion imagery. The ability to construct models of stationary structures from ordinary video data may be applied to commercial applications in recognition of industrial parts and in video surveillance, and extend to detailed terrain mapping, simulation in video gaming or entertainment applications, or a variety of novel, Internet-based services.

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KEYWORDS: Computer Vision, Video Modeling, Range Measurement, 3-D Modeling, Shape from Motion, Image Understanding, 3-D Reconstruction.

SB022-043 **TITLE**: Deep Ultraviolet Laser Diode for UV-Resonance Enhanced Raman Identification of Biological Agents

TECHNOLOGY AREAS: Chemical/Bio Defense, Nuclear Technology

OBJECTIVE: Development of a deep ultraviolet semiconductor laser diode (220 nm – 250 nm) for performing UV-resonance enhanced Raman spectroscopy for the identification of weaponized biological agents in a miniaturized sensor package.

DESCRIPTION: The state-of-the-art technology for biological species identification relies primarily on immunoassays and wet chemistry. A very desirable goal would be the capability to detect and identify specific biological agents in real time, and without wet chemistry. Today, a technique known as laser induced fluorescence (LIF) is used to provide early warning of possible bio-threats. The LIF technique is real-time and does not involve any chemical reagents; however, it can only provide warning—it cannot give actual species identification. The UV-resonance enhanced Raman technique is also a real-time monitor and does not involve wet chemistry; however, the only laser sources available at the needed deep UV wavelengths are generally large power hungry systems. What is needed to make this technique viable for military and homeland defense applications is the development of semiconductor emitters (laser diodes) capable of operating in the wavelength range of 220 nm — 250 nm. Owing to recent advances in materials and devices it is now possible to develop the requisite laser diodes. Specifically, recent advances in high aluminum content nitride semiconductors has yielded continuous wave (CW) room temperature operation at ~365 nm. Also, there are very recent reports of light emission from diamond pn-junctions at ~225 nm. The design, development and optimization of such devices would provide the needed chip-scale light source to enable miniaturized biological agent identification systems to be realized.

PHASE I: Perform a feasibility study through modeling and simulation of a semiconductor laser diode structure appropriate for operation in the range of 220 nm to 250 nm. Assess the feasibility of a manufacturing process flow for the fabrication of the laser diode.

PHASE II: Demonstrate the operation of a pulsed, room temperature laser diode operating in the range of 220 nm to 250 nm. Optimize device structure and materials properties in order to achieve an average optical output power of >10 mW in pulsed mode.

PHASE III DUAL USE APPLICATIONS: The primary application of a deep UV laser diode would be to the optical data storage industry. Recently, industry has placed a major investment in the development of blue and violet laser diodes for the high density DVD market. By going to wavelengths more than 100 nm shorter will allow a many fold increase in optical data storage owing to the smaller spatial spread of short wavelength light. Another major commercial market is in solid-state lighting. Currently, industry is focused on near UV (~390 nm) semiconductor light sources and the development of appropriate phosphors to be excited by those sources. The development of diodes emitting in the near 250 nm ranges would allow industry to use the long established phosphor technology currently employed in fluorescent lamps thus greatly reducing development and production costs.

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KEYWORDS: Ultraviolet Laser Diode, Bio-Agent Identification, UV-Resonance Enhanced Raman.

SB022-044 **TITLE**: High Operating Temperature Mid-Wave Infrared Diodes for Free Space Optical Communications

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Development of high operating temperature mid-wave infrared (MWIR) laser diodes to enable soldier transportable, high bandwidth free space optical communications.

DESCRIPTION: Currently, battlefield communications rely on radio-frequency (RF) technologies. Although RF communications is an effective technology for many applications, it suffers owing to limited achievable bandwidth, and a high susceptibility to intercept, detection, and jamming. A very desirable goal would be the capability to transmit at very high bandwidth and with low probability of intercept and detection, and anti-jamming. Free-space optical communications offers such a possibility. However, one must develop laser diodes operating in the MWIR in order to exploit the highly favorable transmission window in this portion of the spectrum. Within this window, there is minimal attenuation, good penetration of fog, low background and solar flux, and low scintillation. To be practical, these laser diodes must operate at near room temperature, or within thermoelectric cooler range. The design, development and optimization of laser diodes working in the MWIR at high operating temperature would provide the needed chip-scale light source to enable easily soldier transportable free space optical communications on the battlefield. This technology would directly address the need for very high bandwidth communications within the tactical battlespace.

PHASE I: Perform a feasibility study through modeling and simulation of a semiconductor laser diode structure appropriate for high temperature operation in the MWIR. Assess the feasibility of a manufacturing process flow for the fabrication of the laser diode.

PHASE II: Demonstrate the operation of a continuous wave (CW), high operating temperature laser diode operating in the MWIR. Optimize device structure and materials properties in order to achieve higher power and higher operating temperature.

PHASE III DUAL USE APPLICATIONS: The telecommunications industry today is unable to meet business and residential customer demands for high-bandwidth network access services in a cost-effective manner. Despite the fact that over ~ 75% of businesses are less than one mile from the telecom network's high speed fiber backbone (operating at between 2.5 and 10 Gb/s), fewer than ~ 5% of the buildings in the US have direct, high-bandwidth connections to this network. This dilemma is often referred to as the "last mile" problem. The use of free space optical communications is by far the most cost effective solution to this impediment. Last-mile access equipment will represent more than $3 billion in revenue in the next few years according to credible market studies. Thus, the development of high operating temperature MWIR lasers would address a large and rapidly growing commercial market.

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KEYWORDS: MWIR Laser Diode, Interband Cascade Laser, Free Space Optical Communications.

SB022-045 **TITLE**: Design Tools for Integrated Asynchronous Electronic Circuits

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Development and demonstration of Computer Aided Design (CAD) tools for integrated asynchronous (clockless) electronic circuits.

DESCRIPTION: Although synchronous design has enabled the development of high performance integrated circuits of today, many difficulties associated with high-density integration, high clock speeds and power consumption are emerging as fundamental limitations for further scaling of synchronous circuits. In this regard, asynchronous circuit architectures offer the potential to significantly reduce problems associated with interconnect latency, on-chip noise, timing closure and power consumption in high density circuits. Clockless chips have already been demonstrated for high performance applications with significantly reduced power consumption. Despite these prototype demonstrations, asynchronous architectures have not found wide acceptance in the electronics industry due to the lack of an infrastructure to design, test and fabricate asynchronous chips in a reliable, efficient and economical way. The lack of commercially supported CAD tools for asynchronous design has been a significant barrier to developing clockless chips. Although many ad-hoc models are available within the academic community, a comprehensive integrated environment to support the design of asynchronous circuits does not exist. DARPA is interested in exploring the feasibility of developing a new generation of CAD tools and libraries to enable the design of integrated asynchronous electronic circuits.

PHASE I: Develop methodologies for the synthesis and verification of asynchronous electronic circuits. Determine feasibility of designing asynchronous circuit architectures that have orders of magnitude improvement in the ratio of chip performance to power consumption. The Phase I effort will also develop a plan to interface the asynchronous design tools with appropriately modified circuit placement and routing algorithms that enable exploration and optimization of asynchronous circuit architectures for given specifications.

PHASE II: Further develop and extend the tools and concepts developed in Phase I to demonstrate the synthesis, verification and optimization of asynchronous circuit architectures. Develop model libraries and implement methods to enable design-for-testability (DFT) for asynchronous circuit components and sub-blocks/circuits. Develop methods for timing and performance analysis of asynchronous circuits. Demonstrate CAD tools for the coupled optimization of parameters such as integration density, cross talk, timing and power consumption. Perform validation studies to demonstrate the capabilities of the design tools.

Complete documentation of the design methodologies, test cases and the test results must be delivered upon completion of the contract.

PHASE III DUAL USE APPLICATIONS: This effort will form the groundwork for advanced CAD tools for routine analysis and design of integrated asynchronous electronic circuits. These developments will enable the design of a new generation of integrated circuits with superior performance, optimized power consumption and low noise operation. Asynchronous circuits will enable novel high performance sensing, communication and processing systems for current and future military requirements.

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KEYWORDS: Asynchronous Circuits, Timing Closure, Power Consumption, Computer-Aided Design, Thermal Management, On-Chip Noise.

SB022-046 **TITLE**: Non-Contact Final Polish/Passivation Technology for the Production of Epi-Ready GaSb Wafers

TECHNOLOGY AREAS: Materials/Processes, Sensors, Electronics, Battlespace

OBJECTIVE: Develop, using non-contact technologies, a commercially viable, high throughput, and final polish and passivation procedure for producing extremely flat, smooth, epi-ready 2 to 12 inch GaSb wafers.

DESCRIPTION: The events of the past few months have underscored the need for developing ultra-high-speed sensors, imaging and discrimination systems as well as data transfer, processing and communications systems that can be fielded autonomously for remote and covert activities. Portability and extended operability are key parameters. GaSb (Gallium Antimonide) and the antimonide based semiconductor (ABCS) materials are of strong interest because of their potential for being used in very high speed integrated circuits with very-low power-consumption levels. However, GaSb wafer production is currently limited by serious variation in quality from wafer-to-wafer, polishing-run-to-polishing-run, and vendor-to-vendor. Also there is no current agreement to what qualifies as a high-quality epi-ready wafer, that is, a wafer that can be taken from the package and placed directly into a growth system for the application of epitaxial films. This effort will develop dry etching techniques (such as plasma, cluster-ion beam, or chemically-enhanced ion beam techniques) for the non-contact final polish and passivation of a GaSb wafer surface. The process must be robust and commercially viable, producing surfaces with flatness specifications similar to the silicon industry, a surface roughness less than 0.25nm rms, and a passivation layer which is easily removable without any detrimental effects to either the crystalline surface structure of the wafer or to the growth system (such as Molecular Beam Epitaxy (MBE)). The process is expected to be a significant improvement over what is currently considered as state-of-the-art for epi-ready GaSb wafers.

PHASE I: Determine feasibility of a polishing/passivation process which reduces wafers surface roughness to less than 0.25 nm rms and produces superior substrate-epitaxial layer interfaces over those of current standard practice. Feasibility study should include characterization of the processed wafer surface flatness, composition and crystallinity to show epitaxial growth ready (epi-ready) quality.

PHASE II: Develop a method of custom flattening the front surface of each wafer while also performing final polish and passivation using the process demonstrated in Phase I. Scale the process for commercial production and demonstrate commercially viable throughput. Demonstrate a prototype flatten/polish/passivation system by processing wafers supplied by at least two independent GaSb wafer suppliers and provide at least two batches of wafers for epitaxial growth.

PHASE III DUAL USE APPLICATIONS: Development of a commercially viable process and tooling system to flatten, final polish, and passivate GaSb wafers will stimulate the development of both military and commercial high-speed low-power based GaSb sensor, electro-optic and electronic systems by providing the industry with a reliable source of in-spec GaSb wafers.

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KEYWORDS: GaSb, Gallium Antimonide, Wafer, Substrate, Polish, Passivate, Materials, Processes, ABCS, Antimonide Based Semiconductor.

SB022-047 **TITLE**: Large Phased-Array Antenna Multi-Beam Beamformers

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop and validate lightweight phased-array antenna beamformer architectures that enable very large radar antennas to utilize multiple simultaneous beams of moderate to high bandwidth.

DESCRIPTION: Physically large antennas offer significant advantages to radar systems. For example, since the power-aperture product determines search radar performance, a radar system with a large antenna may transmit low radio frequency (RF) power. If the large antenna is a phased-array antenna, design of the receive beamformer (and transmit RF signal distribution) presents several challenges. First, the phased-array antenna must maintain a minimum bandwidth at large off-broadside scanning angles. Second, the beamformer weight per square meter of aperture must be relatively low so that the weight of the large antenna does not exceed specified limitations. Third, the beamformer must support the use of multiple simultaneous search beams. Since the beamwidth is very narrow, search radar with a very large antenna requires multiple simultaneous search beams in order to fully search a sector within a specified time. DARPA is interested in the research and development of innovative phased-array antenna beamformer architecture. In addition to the receive beamformer, all approaches must also consider the transmit signal distribution and the distribution of control signals for beamsteering and calibration. Space feeds are of particular interest due to their potentially minimal weight. Optical beamformers, digital beamformers, and hybrid approaches are also of interest. It should be assumed that the antenna is an active array, operating in the L, S, or X radar bands. The antenna sizes of interest are 40,000 to 400,000 elements. The minimum desired bandwidth is 10 MHz, when scanned 60° off broadsides, to support normal search and track operations. Approaches supporting bandwidths close to 600 MHz at S band or 1,500 MHz at X-band are desirable (but not required) to support target identification. Average radiated power should be assumed to be in the range of 3 to 30 Watts per square meter of antenna, with roughly a 0.10 duty factor. The multi-beam approaches may utilize a spoiled transmit beam, and should support from 4 to 16 simultaneous beams.

PHASE I: Conceptual development of one or more beamformer architectures, including identification of the types of components recommended. Use analysis and simulation to illustrate and quantify performance of the proposed approaches. Produce a transmit loss budget, a receive G/T budget, and directivity patterns. Quantify the bandwidth, and estimate the weight. Address other performance issues that are unique to the architecture.

PHASE II: Fabricate and demonstrate samples of the critical components. Combine demonstrated results with analysis and simulation to illustrate large array beamsteering, transmit loss, receive G/T, directivity patterns, and bandwidth. Validate that the beamsteering timing and control supports typical radar search and track functions.

PHASE III DUAL USE APPLICATIONS: The technology developed under this effort is directly applicable to phased-array antennas used for communications, in both commercial and military applications. Use of large antennas in a communications link increases the transmit gain and the receive power-collecting area. This enables increased data rates; decreased error rates, lower transmit power, and higher receive noise temperature. Design of a beamformer for communications applications suffers challenges very similar to those listed for radar applications, including the need for multiple simultaneous beams. The solutions developed for radar systems will immediately find dual application to communications systems.

KEYWORDS: Radar, Antenna, Phased-Array, Beamformer.

SB022-048 **TITLE**: Innovative Space Materials and Structures

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop next generation space materials, membranes and structures in support of low cost, high performance military space applications.

DESCRIPTION: Space represents the ultimate "high ground" for military applications. Unfortunately, access to space is fundamentally very expensive and difficult due to both launch costs and the logistics of human assembly on orbit. Thus, it is highly desireable to develop new materials and space structures that have extremely low stowed volumes and weight, reliable automated deployment, and durability in a space environment. DARPA is interested in the research and development of innovative space materials and structures concepts that have the potential to provide major breakthroughs in either affordable access (i.e., extremely small payloads) or feasibility of much higher performance systems (i.e., extremely large space systems) that can be launched affordably on smaller delivery systems. Example materials and constituent structural materials include (but are not limited to) rigidized inflatables, Gossamer membranes and/or structures, composites, and piezoelectric materials. These materials must also be able to withstand severe radiation and thermal environments and have a long service life.

PHASE I: Identify space materials, components and structures with greatest potential payoff for military applications of space. Use analysis, simulation and possibly experimentation to illustrate and quantify performance of the proposed approaches. Develop a technology development roadmap including a technology readiness level (TRL) timeline.

PHASE II: Fabricate and demonstrate meaningful scaled models. Combine demonstrated results with analysis and predictive tools to illustrate full-up performance. Refine TRL maturation plans to include possible space based demonstration plan.

PHASE III DUAL USE APPLICATIONS: Technologies developed under this effort will have a multitude of directly applicable military and commercial applications for communications, remote sensing (Electro-Optical/Infra-Red (EO/IR), optical, radio frequency (RF)), and space exploration. Many of these technologies will also greatly aid multinational space exploration activities including the manned space station and NASA's New Millennium Project.

KEYWORDS: Space, Gossamer Structures, Rigidized Inflatables, Radiation Tolerant, Long Life, Reliable Deployment, Coefficient of Thermal Expansion (CTE).

SB022-049 **TITLE**: Modular Micro-Satellite Bus

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Design, build, and test an innovative, modular microsatellite bus with interfaces to facilitate rapid integration of a variety of payloads.

DESCRIPTION: Satellite payloads have advanced so that microsatellites (50-100kg total mass) can provide substantial utility for national security missions. Ongoing research (Ref 1) will develop a responsive launch capability for microsatellites into Launch and Early Orbits (LEO). The objective of this topic is to develop an innovative common microsatellite bus that: 1) maximizes payload fraction of the total satellite mass; 2) maximizes power available for the payload(s); 3) maximizes onboard computer capability available for data processing and 4) minimizes payload integration time by providing a clean separation plane between bus and payload. The objective system would have satellite buses (perhaps with separate propulsion modules) and instruments in storage, capable of payload integration with the bus and checkout to be complete in a matter of hours, with the specific mix payload determined as needed. (Similar to adding a hardware peripheral and loading its associated driver to a desktop computer.) The use of modular design and fabrication to the greatest extent possible is desired in the bus to facilitate rapid processing. The bus architecture should also enable rapid loading and test of mission specific software. On-orbit, the microsatellites would operate autonomously, communicating with the ground only when significant events occur.

PHASE I: Identify key microsatellite bus subsystems for aggressive miniaturization, explore technologies to provide power, both CW and in burst mode, identify innovative approaches to provide interfaces for payloads, and identify innovative approaches to reduce system integration and check-out time, and identify key issues for demonstration in Phase II.

PHASE II: Develop and demonstrate key subsystems and validate performance. Develop a system level design for a microsatellite bus with modular interfaces.

PHASE III DUAL USE APPLICATIONS: With a responsive launch capability for microsatellites and a standard bus, it could become affordable to fly single scientific instruments, opening up research vistas for universities. New applications, such as communication networks based on constellations of microsatellites, could also be enabled.

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KEYWORDS: Microsatellites, Rapid Payload Integration.

SB022-050 **TITLE**: Small, Heavy Fuel, Compression Ignition Small UAV Engines

TECHNOLOGY AREAS: Air Platform

ACQUISITION PROGRAM: Small UAV

DOD ACQUISITION PROGRAM SUPPORTING THIS TOPIC:

OBJECTIVE: Development of highly efficient, small diesel engines (suitable for small UAVs) is needed to satisfy the standard DoD heavy fuel requirement. There are no engines currently available to meet this requirement.

DESCRIPTION: Small model aircraft engines are commercially available as units and conversion components. These engines are designed to run on model aircraft fuel, which is modified with high volatility ether for ease of starting. For use by DoD, small diesel engines would be required to operate on standard DoD heavy fuels, such as JP8 (MIL-T-83133), with no volatile additives allowed. Development of highly efficient, small diesel engines (suitable for small UAVs) is needed to satisfy the standard DoD heavy fuel requirement. There are no engines currently available to meet this requirement.

PHASE I: Conduct a feasibility concept design of a propulsion system that can operate at a thrust to weight ratio of 2. The weight of the propulsion system includes the engine, starter/generator, battery / energy storage design, 7.5 inch diameter fan / propeller, and 1/2 pound of JP-8 / Diesel fuel (including fuel delivery system). The cold starting system, that is included in the system weight, can also turn the fan / propeller and its thrust can be added to the system thrust (i.e. hybrid diesel electric system). Also designs of multiple cylinder engines (with each cylinder producing 1 to 1.5 hp) is also of interest as a growth version.

PHASE II: Proof of Concept evaluation of a 100-hour operational life with 25 start / stop cycles using both commercial diesel and JP8 fuel (with no volatile additives) on two COTS, modified COTS, or prototype engines running on compression ignition. The engine will produce 1 to 1.5 hp per cylinder. Demonstrate a specific fuel consumption (SFC) of less than 1.0 lbs/hp-hr (at sea level) over a wide operating rpm range, while producing at least 1.2 hp per cylinder (at sea level) and meet an estimated production cost of less than $500 each (1,000 lot quantities) for the engine. The weight goal for the engine is 1 pound. Demonstrate a cold starting system that is portable, reliable, and inexpensive to produce. Provide an analysis with supporting documentation that explains how final production design will meet or exceed cost, power, weight, and system performance objectives. Provide two samples of the prototype engine system.

PHASE III: Continue development of the engines to demonstrate an SFC of less than 0.7 lbs/hp-hr (at sea level) and specific output of 1.3 hp (at sea level) while increasing endurance using both heavy fuels. Meet the designated weight goals for the engine. Demonstrate operation of the engines in appropriate ducted fan air vehicles, meeting SFC and power requirements. Estimate cost of production for 200 lot and 1,000 lot purchases of the engine. Provide an analysis with supporting documentation that explains how final production design will meet or exceed cost, power, weight, and system performance objectives. Provide ten samples of the prototype engine system.

PHASE III DUAL USE APPLICATIONS: Small, efficient, diesel engines designed to operate on standard turbine engine aviation fuels will have commercial application.

KEYWORDS: Engines; Internal Combustion, Diesel Fuel, Specific Fuel Consumption, SFC, Engine Starting; JP5 / JP8; UAV.

SB022-051 **TITLE**: Dismounted Combatant Discrimination for Aircraft Systems

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop robust technology for autonomous discrimination of dismounted combatants and non-combatants using sensor technology applicable to rotorcraft.

DESCRIPTION: The military utility of unmanned platforms as a force multiplier has been demonstrated by the recent conflict in Afghanistan. Emerging unmanned combat aircraft are extending current UAV capabilities to include engagement with the enemy during close-in offensive operations. During these operations, dismounted infantry, who may be intermixed with non-combatants, pose a significant problem. Approaches that require UAV operators to manually detect, avoid, and engage dismounted infantry are not sufficient for these real-time threats. New solutions are sought for autonomous discrimination between combatants and non-combatants using UAV sensors. Recent advances in computer vision have enabled robust video surveillance algorithms that detect, track, and perform coarse classification of moving objects based on visual features. But effective combatant discrimination may require application of behavioral models. This topic requires the integration of sufficient evidential cues, such as appearance and behavioral clues, for reliably detecting combatants under day and nighttime operations. The research should consider environmental factors, clutter, and partial occlusion that commonly occur in unstructured scenes; and may utilize stereo and/or other UAV sensors (e.g. infrared (IR), laser radar (LADAR)) to improve the classification rate and reduce false alarms.

PHASE I: Define a combatant discrimination algorithm and the applicable sensor characteristics needed along with measures of performance. Compare and contrast the approach against alternative techniques. Explore the effect of different operational scenarios on estimated algorithm performance.

PHASE II: Develop a prototype system capable of supporting a proof-of-concept demonstration with surrogate air platforms.

PHASE III DUAL USE APPLICATIONS: The methodology, specific algorithms, and software developed will have applications to autonomous or semi-autonomous surveillance systems in a wide variety of DoD mission areas. Potential DoD applications include advanced target recognition, threat avoidance, and homeland defense. Commercial applications include video surveillance, building security, and operational safety monitoring.

KEYWORDS: Target Classification; UAV; Automated Target Recognition.